



## Modular, Parallel Pulse-Shaping Filter Architectures

Properties of filters and signals would be exploited to simplify processing circuits.

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Novel architectures based on parallel subconvolution frequency-domain filtering methods have been developed for modular processing rate reduction of discrete-time pulse-shaping filters. Such pulse-shaping is desirable and often necessary to obtain bandwidth efficiency in very-high-rate wireless communications systems. In principle, this processing could be implemented in very-large-scale integrated (VLSI) circuits. Whereas other approaches to digital pulse-shaping are based primarily on time-domain processing concepts, the theory and design rules of the architectures presented here are founded on frequency-domain processing that has advantages in certain systems.

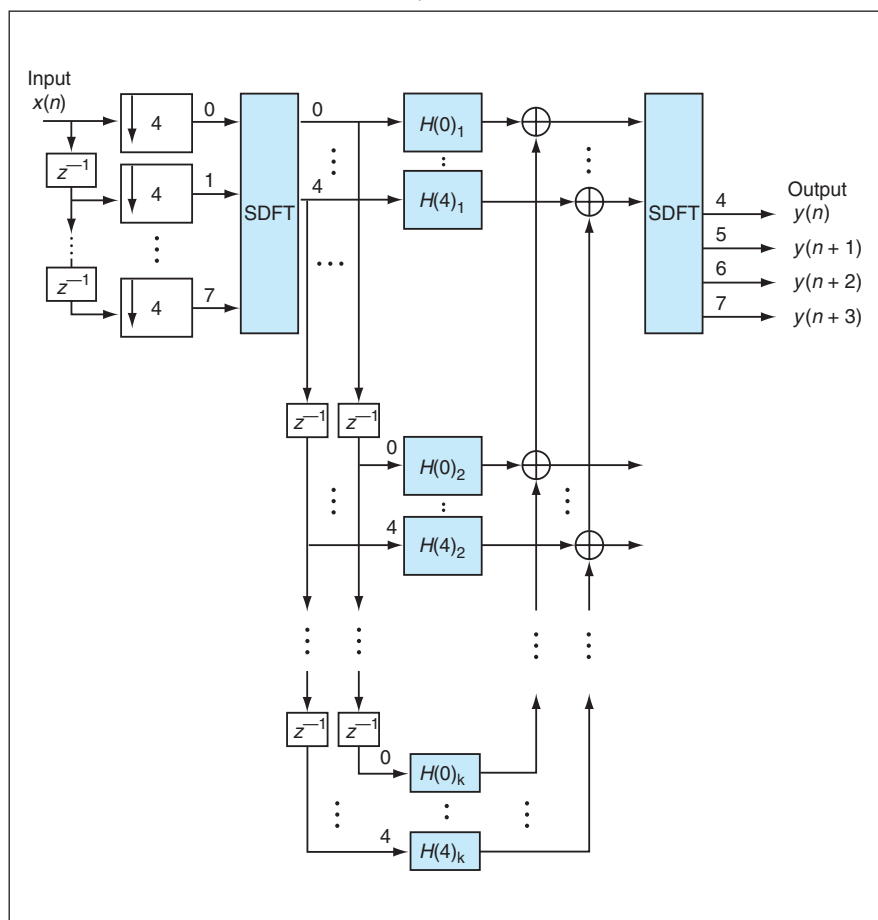
A major advantage of parallel processing of signal data, whether for shaping pulses or other purposes, is that the data rate in each of the parallel streams is much lower than the overall data rate. This makes it possible to use processing circuitry that is slower than what would be needed to process all of the data in a single stream. In particular, it becomes possible to use complementary metal oxide semiconductor (CMOS) circuitry instead of faster and more expensive GaAs-based circuitry. The present frequency-domain approach to parallel processing offers the following additional advantages:

- Certain processing architectures are arbitrarily scalable, such that filter orders and reductions in processing rates can be chosen independently of each other without altering FFT-IFFT lengths. While this is generally true in time-domain approaches, it has not, heretofore, been the case in frequency-domain approaches without altering FFT-IFFT lengths.
- Under many circumstances using the frequency-domain approach entails fewer computations per filtered output than time-domain counterparts. Therefore, fewer transistors and/or lower power consumption may result from such an implementation.
- The ability to manipulate phase and frequency bands in the frequency-domain approach may have advantages

in some systems employing time-varying new and simple subconvolution filtering methods as well as prior developments in discrete-time signal processing, multi-rate filtering, and general linear-systems theory. The theoretical derivation begins with the subdivision of a time-domain convolution into a number of subconvolutions. The subconvolutions are recast as combinations of subsampling (decimation) in parallel, variously delayed streams to obtain parallel-processable pairs of specialized discrete Fourier transforms (SDFTs) and their inverses (SIDFTs) (see figure). The specialization lies in the elimination of redundant and unnecessary

computations by (1) skipping over terms that are known to be identically zero and (2) exploiting the fact that in the frequency-domain representation of the desired filter response, each negative-frequency component is the complex conjugate of the corresponding positive-frequency component. Additional simplifications are made on the basis of the (up-sampled) nature of the input signal. Modularization and expanded parallel operation can be effected by splitting the filtering across multiple blocks.

This work was done by Andrew A. Gray of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).  
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The Subconvolution Filtering Architecture represented by this diagram is an example for a case of decimation by 4 (1/4th rate processing) and a pulse-shaping filter of order  $k$ . The symbol " $\downarrow 4$ " represents decimation by 4, the  $H$  quantities are frequency-domain filter coefficients, and the  $z^{-1}$  signifies a delay equal to one input sample period.